MULTIOBJECTIVE ONBOARD EXPERIMENT FOR ADVANCED RESEARCHES ON ROBOTICS, CONTROL SYSTEMS AND MATERIALS BEHAVIOUR

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GLOBAL OBJECTIVES OF THE STUDY

1. Design and set up of an experimental test-bed to study maneuvering and structural vibration control of a multi-body flexible system.
2. Study of the following problems: micro-meteorites and micro-debris impact, erosion by atomic oxygen, outgassing, functionality under thermo-elastic deformations.

The utilization of an Express Pallett Adapter (half of the available volume) of the International Space Station is proposed for the on orbit experimentation. The experimental test-bed is conceptually composed of three modular volumes, as in Fig.1. While the external volumes house two pairs of manipulators, the internal volume contains the electrical power and control electronics components. Each pair of manipulators is constituted by a master robot, having one rotational d.o.f. and one slave robot, coplanar to the first and with two rotational d.o.f.. While the manipulators of one of the slave-master couples will be built with conventional structure materials (Aluminum) and will have usual deformation sensors (strain gauges), the other will be built using composite materials with integrated fiber optics deformation sensors. All the robot joints will be actuated by brushless, direct drive motors.
The proposed study is divided in five project packages, which are briefly described here below.

OPTIMIZATION OF THE CONFIGURATION AND UTILIZATION OF INNOVATIVE MATERIALS IN SPACE ROBOTIC SYSTEMS

The main task of the configuration design is to maximize the cooperation between the master and slave manipulators. In order to achieve that optimum, the length of the master robot path within the workspace of the slave robot has been maximized by a parametric search. The imposed constraints were the available experimental area, which is a rectangular plane of 1.244 X 0.865 m, and the maximum angular displacements of the joints, assumed as 180 deg for the shoulder and 270 deg for the elbow. The assumed free variables were the positions of the shoulder joint axis, and the length of the links. Figure 2 reports the calculated optimal solution. The beam elements of the link have been designed to have the first bending vibration frequency equal to 1 Hz, for each link, both for the conventional and the advanced materials manipulators. In order to choose the motors, a typical maneuver has been imposed and the maximum needed torques computed. Table 1 reports the main data, which are common for both manipulator couples. Figure 3 shows a FEM model of the composite material slave robot, under second bending mode deformation.

AUTOMATIC GENERATION OF EFFICIENT SIMULATION MODELS OF FLEXIBLE ROBOTIC MANIPULATORS

This study has two main tasks: first, a computationally efficient dynamics model of the system is obtained by a symbolic computation algorithm (Composite Flexible Body), which exploits the assumed modes method to describe flexibility. The dynamic model obtained is more numerical efficient than the one obtained by the Eulero-Lagrange approach.
Then, that dynamic model is automatically loaded in an S-function of a Simulink block diagram, in order to be numerically integrated. Figure 4 illustrates this procedure.

SENSORS FOR ARTIFICIAL VISION IN ROBOTICS

To track the relative motion between slave and master robot an artificial vision sensor assembly has been designed. As shown in Fig.5, this system is constituted by a digital camera mounted on an actuated rotational joint at the tip of each slave robot and a square target, with four l.e.d.s mounted at the tip of the master robots. The developed algorithms carry out a sequence of image processing steps, in order to obtain the relative position of the camera with respect to the target.
The spherical deformation defect due to the optical lenses

is software compensated. The position measurements, which are obtained at a high rate, can be used for the control feedback.

FUZZY LOGIC ACTIVE CONTROL

A control system for vibration suppression, using a fuzzy microprocessor, has been developed. The utilization of fuzzy controllers does not require a rigorous definition of the system dynamics and can be used to control nonlinear complex systems.

A stand-alone electronic board has been purposely designed and built (see Fig.6). The board also carries out the conversion and conditioning of the input and output signals. The fuzzy micro-controller is a programmable device. In fact the control algorithm is memorized on an integrated EPROM type memory.

The stand-alone board has a computation capability equivalent to a normal personal computer, but it is completely dedicated and optimized for the control. By using miniaturised components (SMD) the stand-alone board is well suited to minimize the area occupied by the control system.

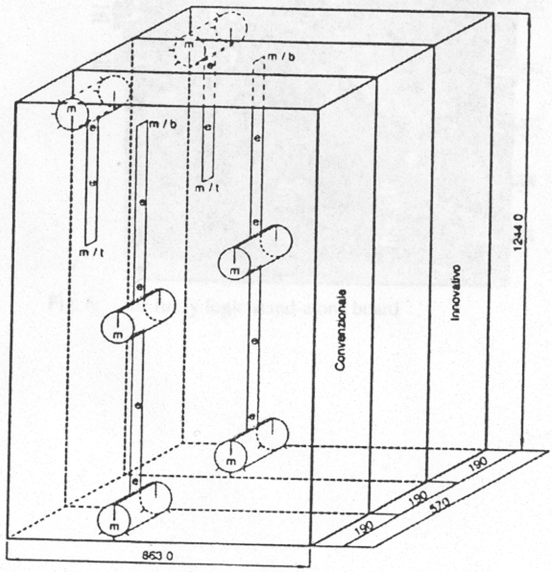

Fig. 1: schematic view of the experiment

OPEN LOOP CONTROL LAWS FOR FLEXIBLE ROBOTIC MANIPULATORS

An open loop control motion input is computed, aiming at reducing the residual structural vibrations at the end of the maneuvers. The proposed control technique pre-shapes the reference motion applied to each joint. The method is based on the convolution of a suitable sequence of impulses, whose amplitude and phase are based on the first system frequency, with the reference signal.

The utilization of this control approach requires an accurate characterization of the system to be controlled, in order to precisely determine the natural frequencies and structural damping.

Preliminary tests on real manipulators and models have demonstrated the possibility of obtaining a vibration reduction of more than 80 % with respect to simple feed-forward control.

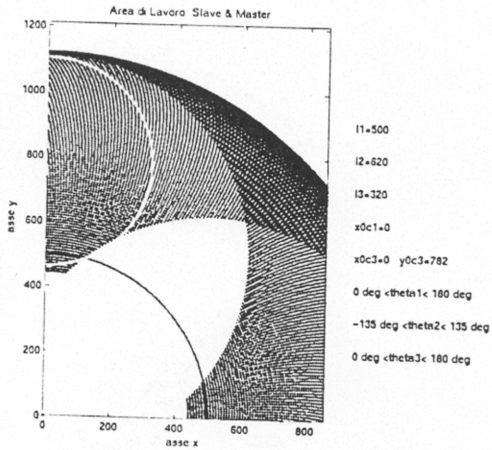

Fig. 2: the optimal geometric configuration

Slave manipulator		
	Arm	Forearm
Length [m]	0,50	0,62
Height [m]	6,50E-02	5,00E-02
Master manipulator		
Length [m]	0.32	
Height [m]	5,00E-02	
Shoulder motor		
Mass [kg]	0.2	
Max torque [Nm]	0.806	
Elbow motor		
Mass [kg]	0.2	
Max torque [Nm]	0.53	

Tab. 1: main data of the robots

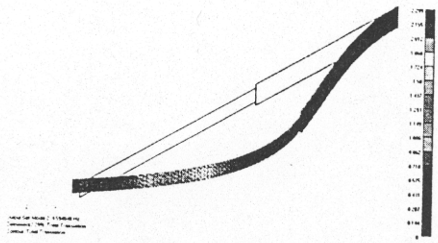

Fig. 3: FEM model of slave robot

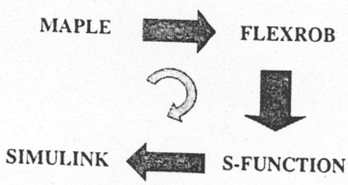

Fig. 4: generation of dynamic model

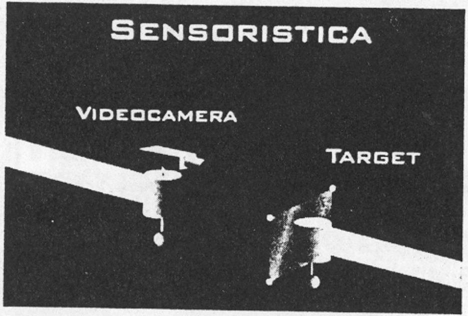

Fig. 5: the artificial vision sensor concept

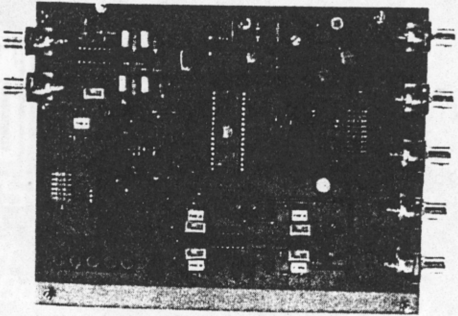

Fig. 6: the fuzzy logic stand-alone board